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Overview of the Stream Functions Pyramid

Will Harman, PG

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We will control the river!

No you won’t!

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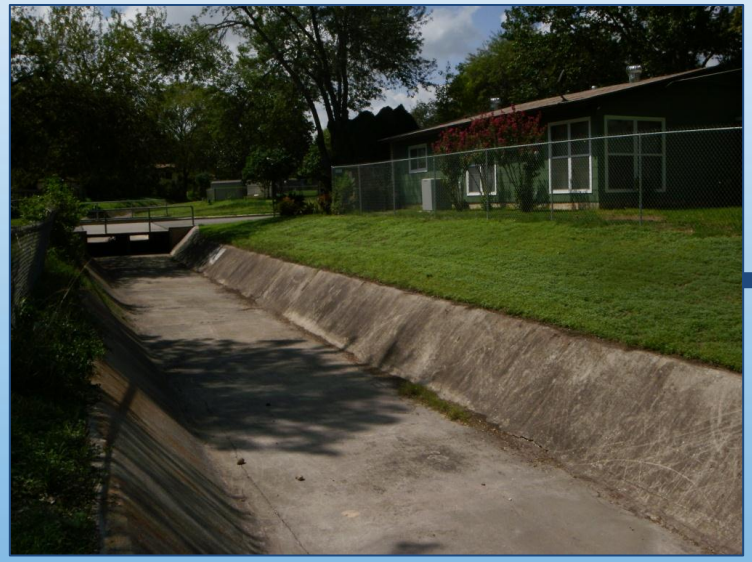
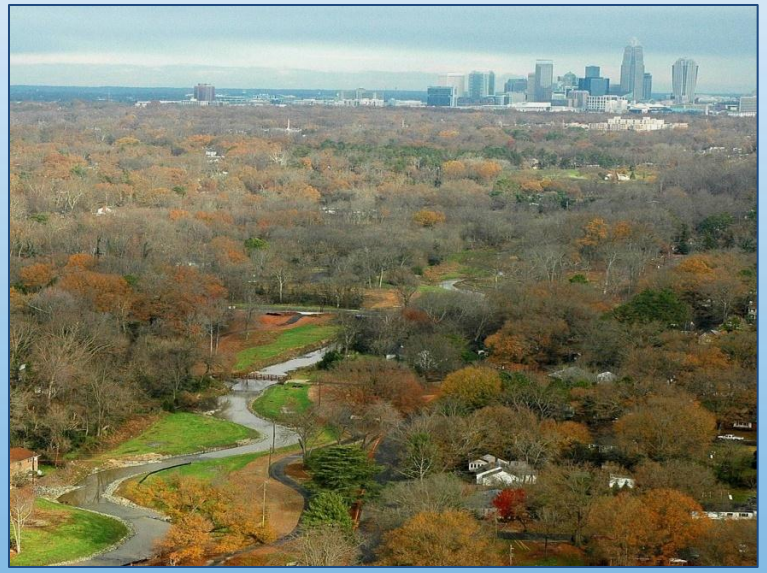
20th Century Shift



Traditional Channel Design

Transport water quickly; Bed and banks don't move



Natural Channel Design

Create a dimension, pattern, and profile that transports water and sediment.

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Source: Michael Baker Corporation

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Source: Michael Baker Corporation

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“State spends $140 million on faulty water projects”

Raleigh News and Observer

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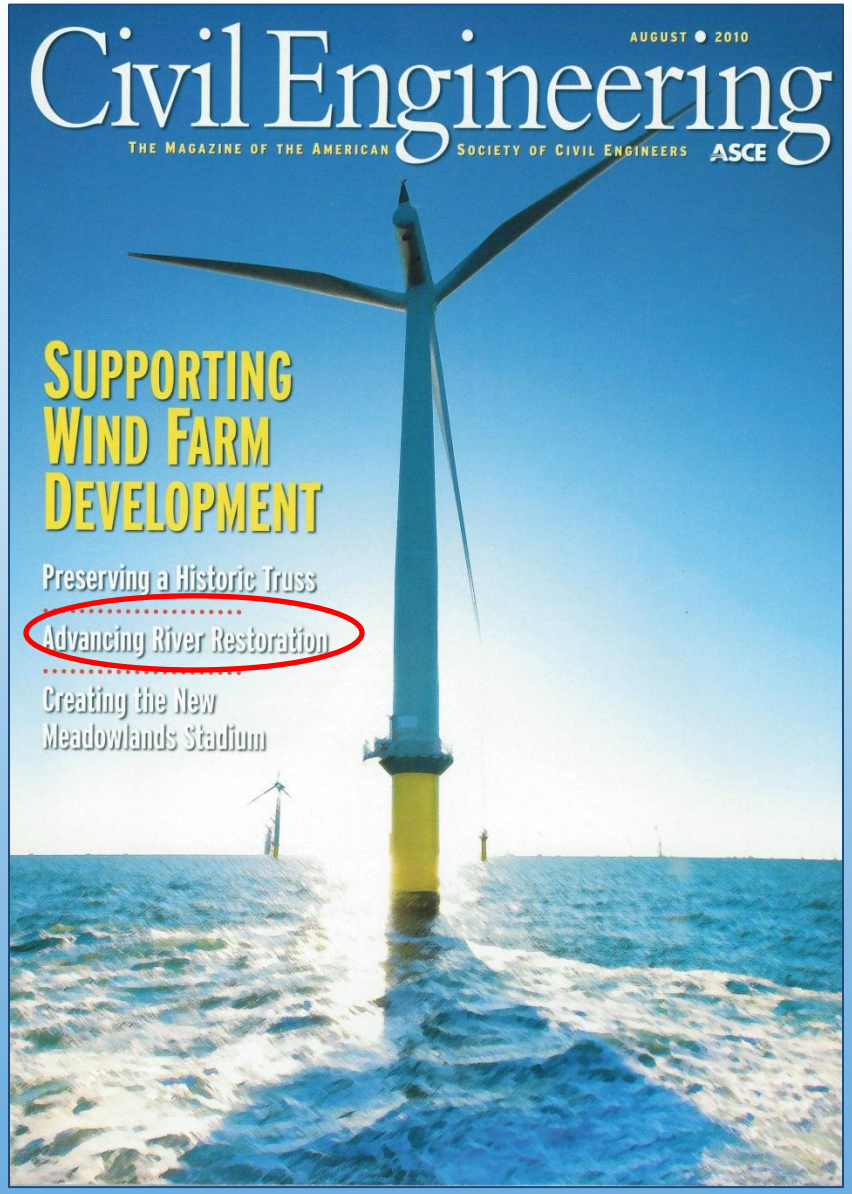

Entering the Mainstream

Stream and river restoration is a fast-growing field that holds significant promise as a means of returning many of the nation's waterways to a more natural condition while also providing numerous other benefits. As the relatively young field begins to mature, civil engineers and practitioners from a host of other disciplines are working together to improve the practice of restoration and extend its benefits to a growing number of streams and rivers across the country. ····· **BY JAY LANDERS**

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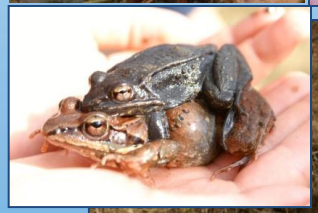
21st Century Goal

Restoration of Dimension, Pattern, and Profile → Restoration of **Functions**





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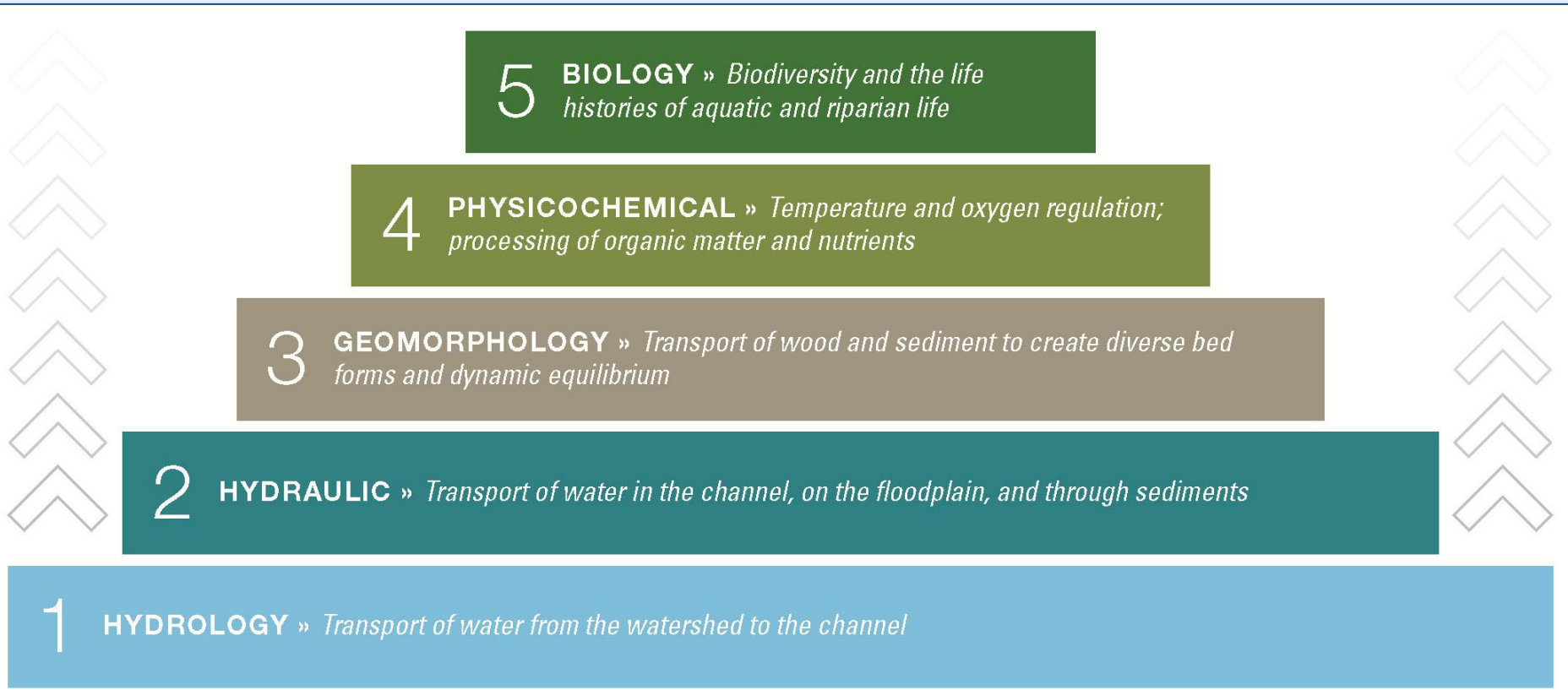
Stream Functions Pyramid



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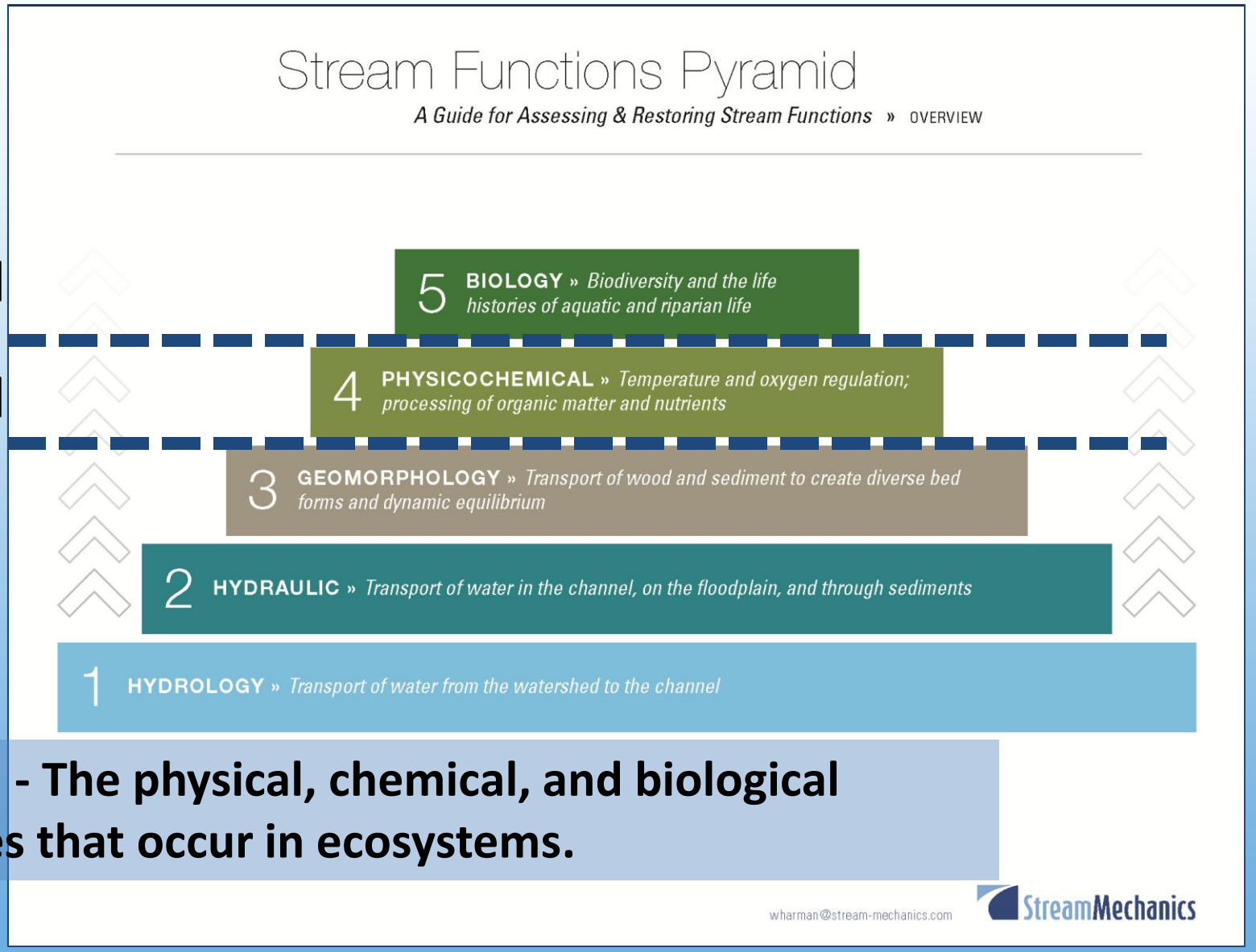
Biological

Chemical

Physical



Function - The physical, chemical, and biological processes that occur in ecosystems.

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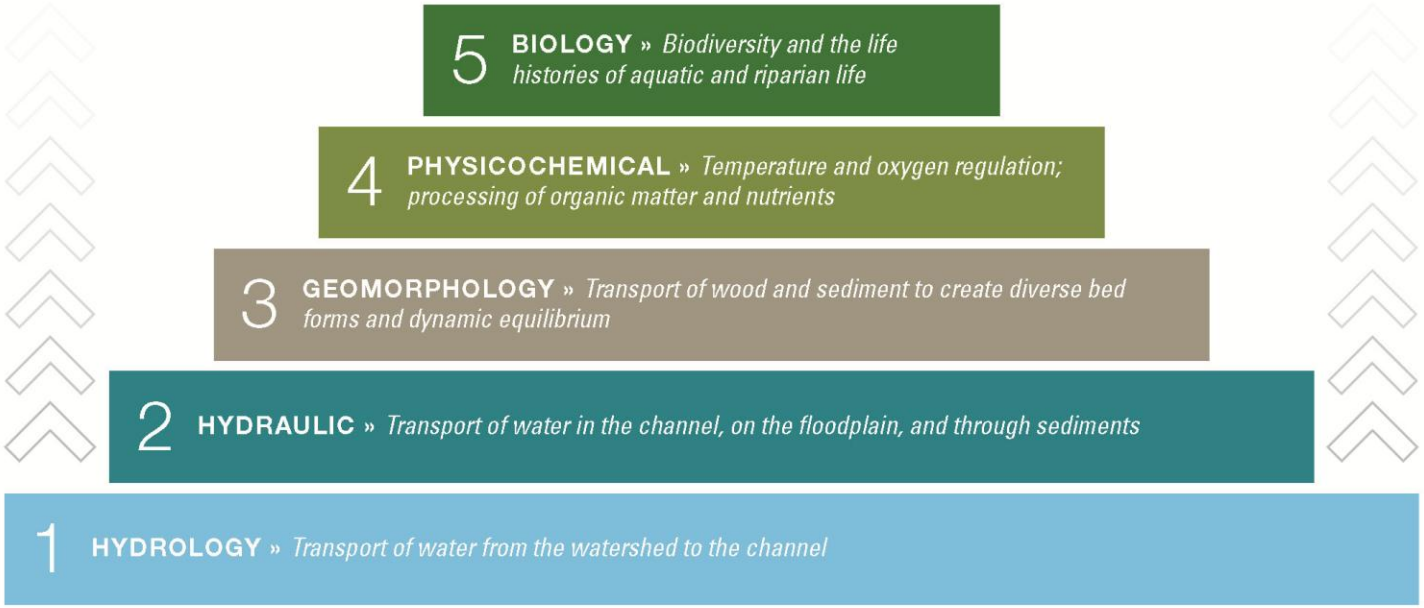
Effect

Cause

Stream Functions Pyramid

A Guide for Assessing & Restoring Stream Functions » OVERVIEW



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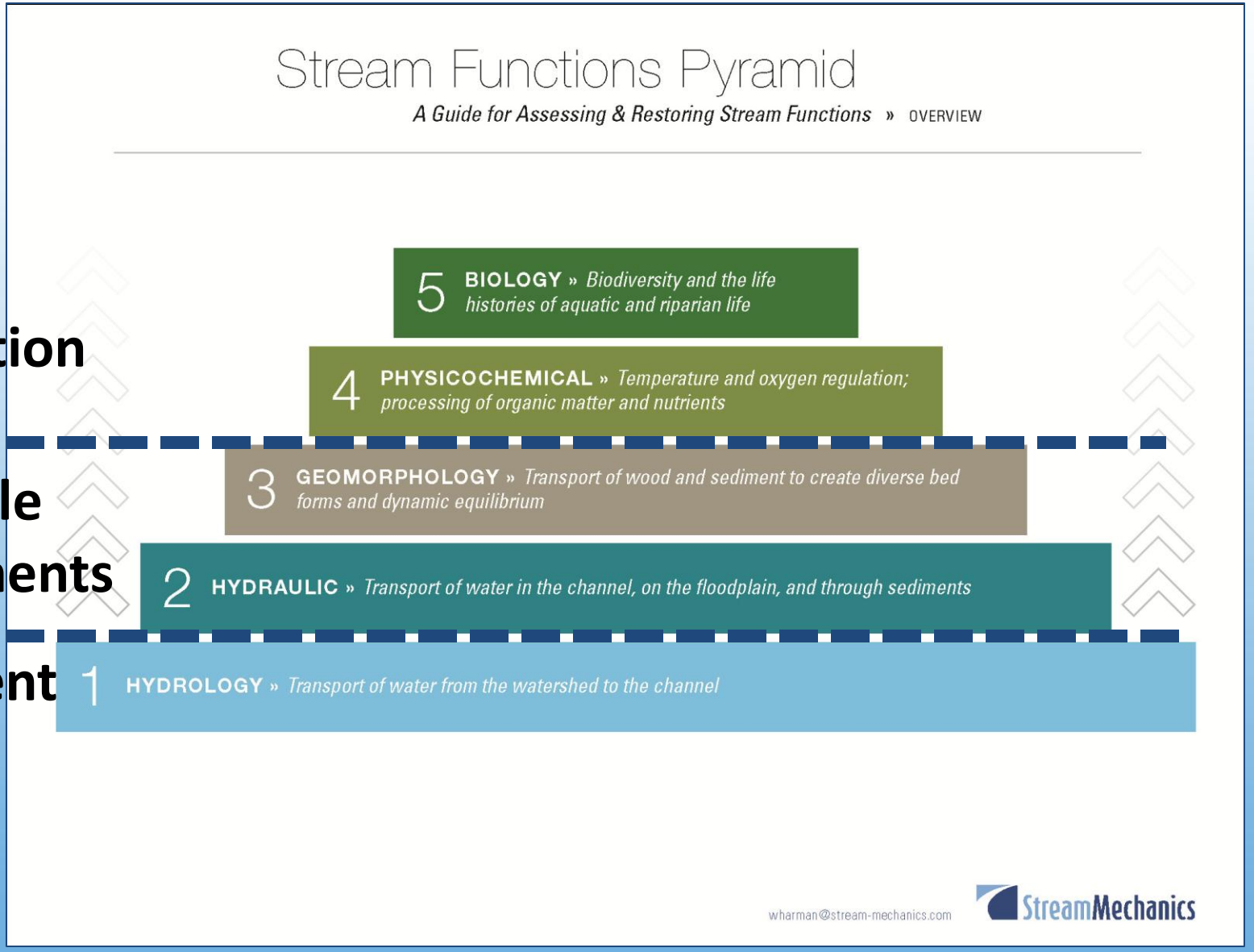
Site Selection

Reach Scale Improvements

Independent Variables



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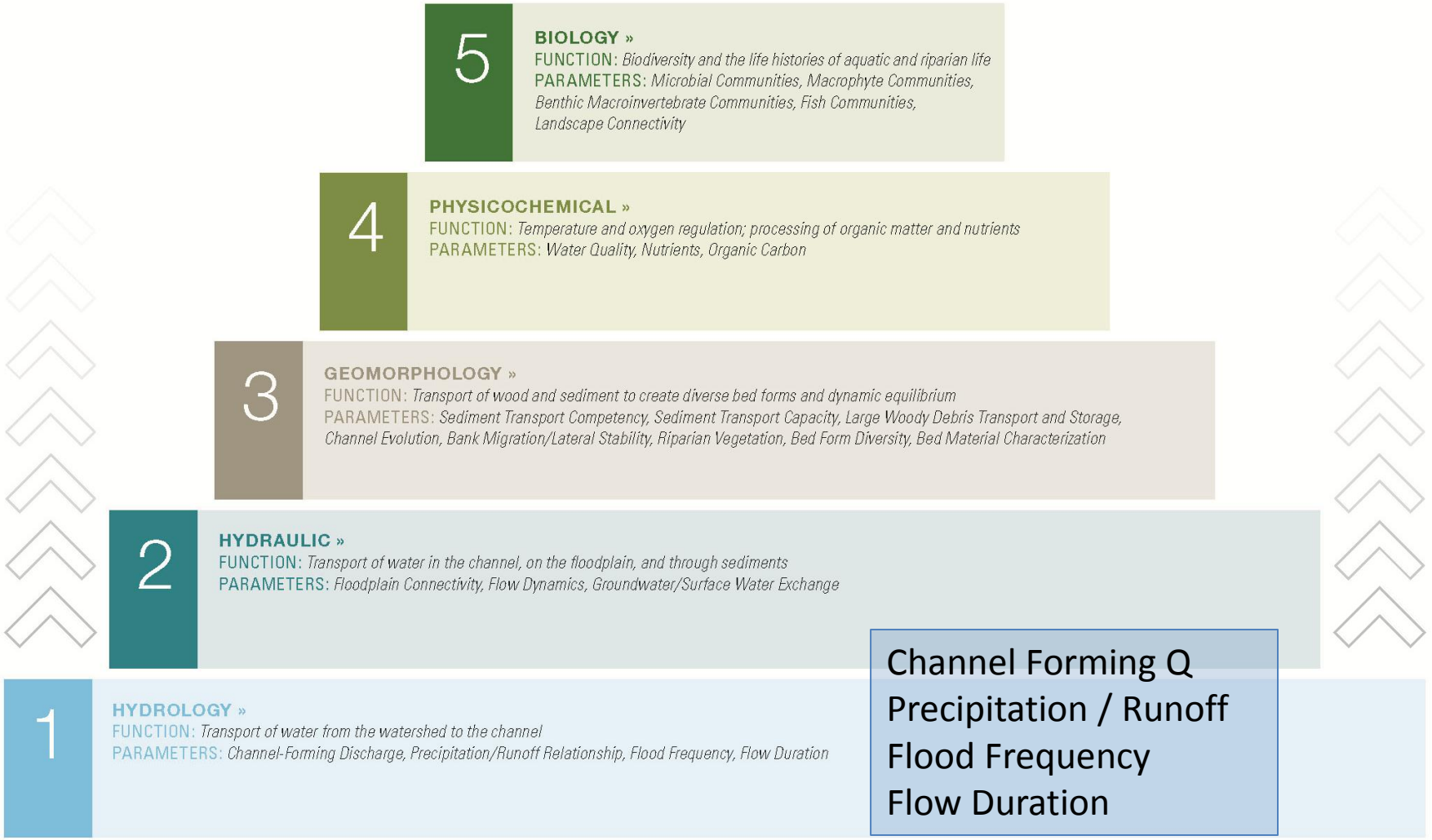
Pyramid and Parameters



Channel Forming Q
Precipitation / Runoff
Flood Frequency
Flow Duration

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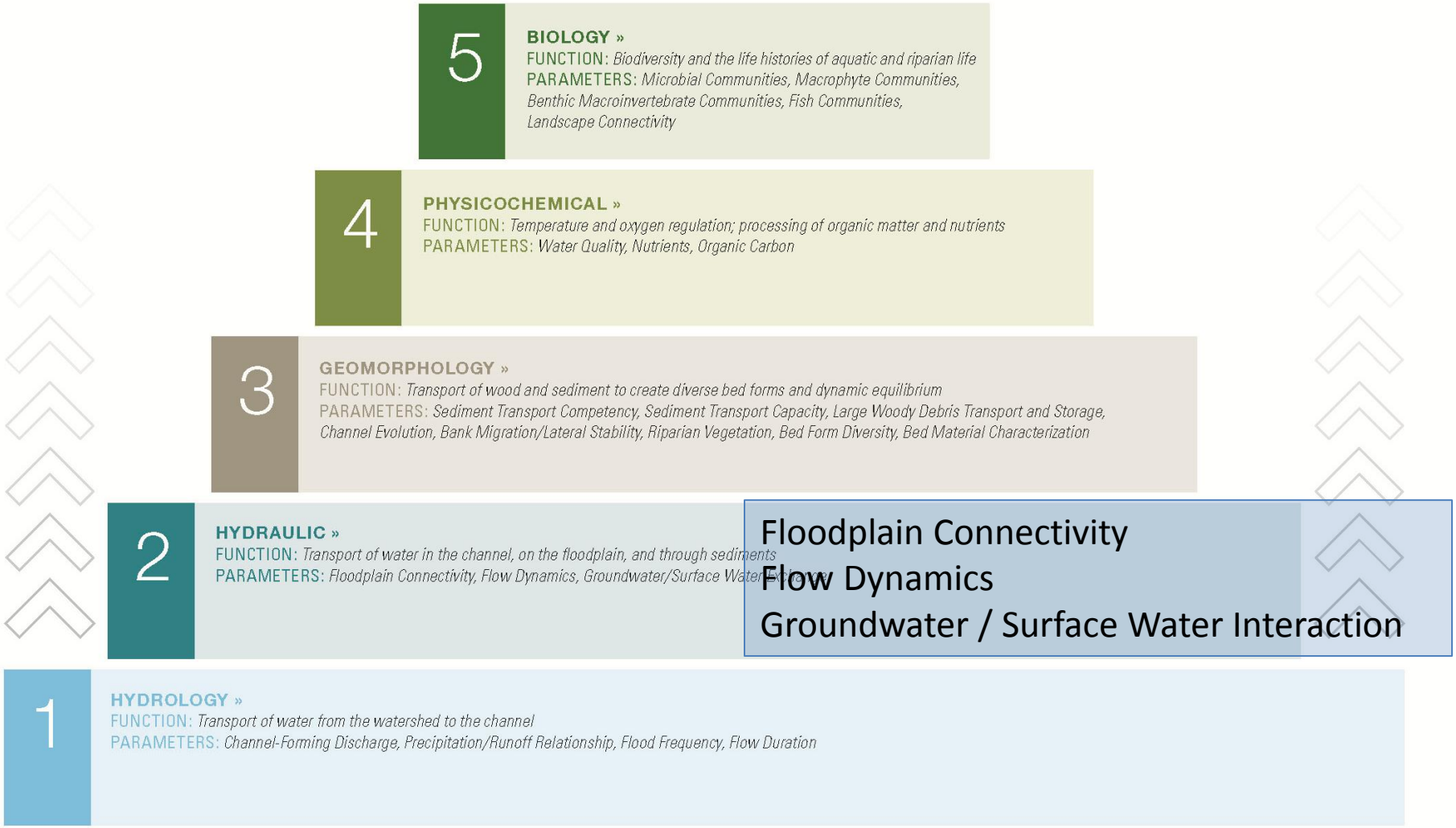
Pyramid and Parameters



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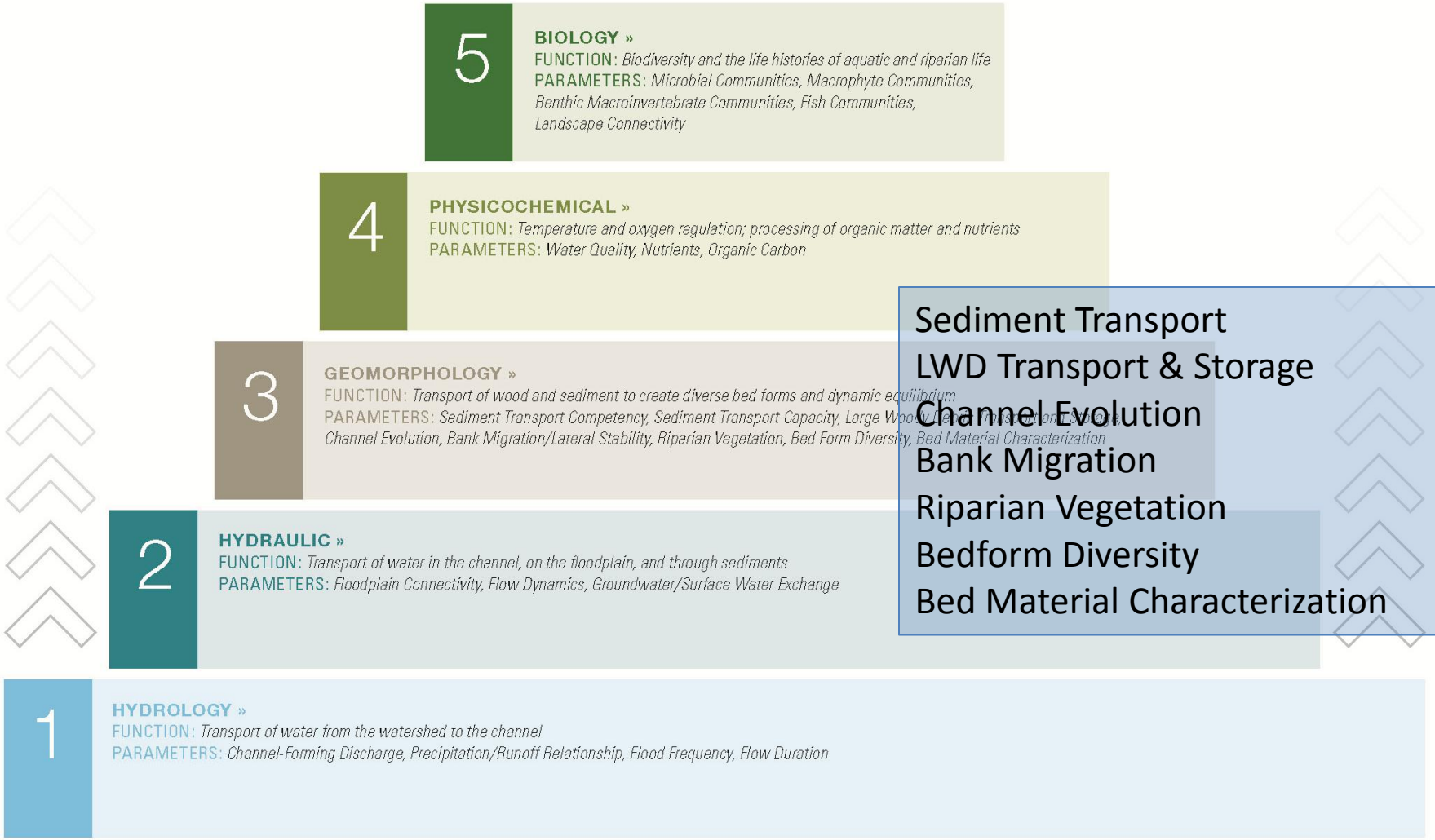
Pyramid and Parameters



Sediment Transport
LWD Transport & Storage
Channel Evolution
Bank Migration
Riparian Vegetation
Bedform Diversity
Bed Material Characterization

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Pyramid and Parameters

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Pyramid and Parameters

Macroinvertebrate Communities
Fish Communities
Microbial Communities
Landscape Connectivity

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Parameters and Measurement Methods

APPENDIX A.c. Parameters and Measurement Methods

HYDROLOGY	
Parameter	**Measurement Method**
Channel-Forming Discharge	1. Regional Curves
Precipitation/Runoff Relationship	1. Rational Method 2. HEC-HMS 3. USGS Regional Regression Equations
Flood Frequency	1. Bulletin 17b
Flow Duration	1. Flow Duration C 2. Crest Gage 3. Monitoring Devi 4. Rapid Indicators

HYDRAULICS	
Parameter	**Measurement Metho**
Floodplain Connectivity	1. Bank ht Rati 2. Entrenchment R 3. Stage versus Dis
Flow Dynamics	1. Stream Velocity 2. Shear Stress 3. Stream Power
Groundwater/Surface Water Exchange	1. Piezometers 2. Tracers 3. Seepage Meters

Parameter	Measurement Method
Floodplain Connectivity	1. Bank Height Ratio 2. Entrenchment Ratio 3. Stage/Q Relationships

BIOLOGY	
Parameter	**Measurement Method**
Microbial Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Macrophyte Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Benthic Macroinvertebrate Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Fish Communities	1. Taxonomic Methods 2. Non-Taxonomic Methods 3. Biological Indices
Landscape Connectivity	1. Spatial Analysis 2. Species Tracking 3. Habitat Models

GEOMORPHOLOGY	
Parameter	**Measurement Method**
Sediment Transport Competency	1. Shear Stress Curve 2. Required Depth and Slope 3. Spreadsheets and Computer Models
Sediment Transport Capacity	1. Computer Models 2. FLOWSED and POWERSED
	2. Buffer Density 3. Buffer Composition 4. Buffer Growth 5. Canopy Density 6. Proper Functioning Condition (PFC)
Bed Form Diversity	1. Percent Riffle and Pool 2. Facet Slope 3. Pool-to-Pool Spacing 4. Depth Variability
Bed Material Characterization	1. Bevenger and King (1995) 2. Riffle Stability Index (RSI)

PHYSIOCHEMICAL	
Parameter	**Measurement Method**
Basic Water Chemistry	1. Temperature 2. Dissolved Oxygen 3. Conductivity 4. pH 5. Turbidity
Nutrients	1. Field test kits using reagents reactions 2. Laboratory analysis
Organic Carbon	1. Laboratory analysis

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Performance Standards
Floodplain Connectivity Example

Measurement Method	Functioning	Functioning-At-Risk	Not Functioning
Bank Height Ratio (BHR)	1.0 to 1.2	1.3 to 1.5	> 1.5
Entrenchment Ratio (ER) for C and E Stream Types	> 2.2	2.0 to 2.2	< 2.0
Entrenchment Ratio (ER) for B and Bc Stream Types	> 1.4	1.2 to 1.4	< 1.2
Dimensionless rating curve	Project site Q/Q_{bkf} plots on the curve	Project site Q/Q_{bkf} plots above the curve	Project site Q/Q_{bkf} of 2.0 plots above 1.6 for $d/_{dbkf}$

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How can we use the pyramid?
-Application-

Function-Based Assessments

Goals and Objectives

Debit and Credit Determination

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Function-Based Assessments

Why do we need them?

- Is this stream sick?
- Is the stream moving towards stability or instability?
- Was there functional lift?
- Was this project successful?
- What reaches in the watershed need restoration?

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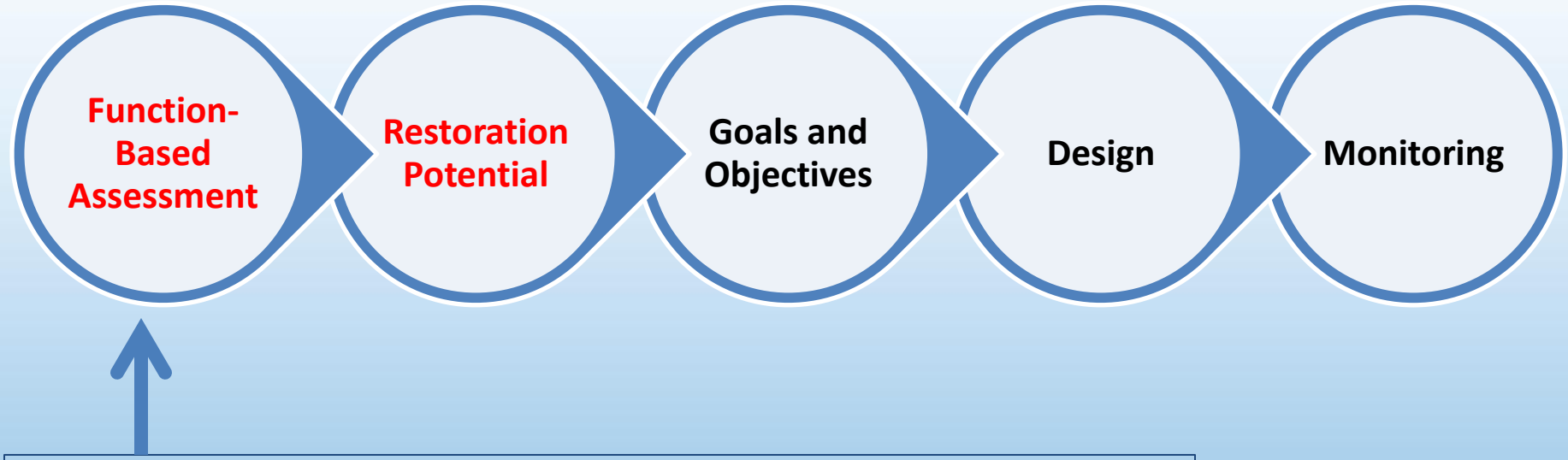

- Establish the Current Functional Condition
- Channel Evolution
- Stressors
- Constraints

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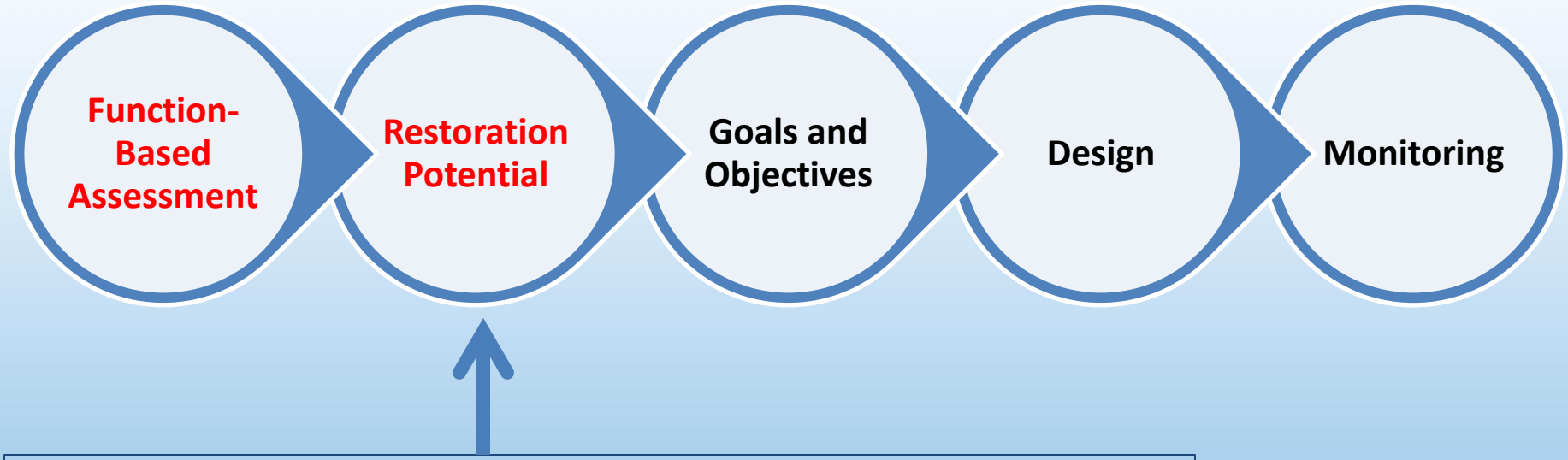

- **What is the highest level of restoration that can be achieved, given the watershed conditions function-based assessment and constraints?**

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Using the Pyramid to show Functional Lift

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition		Post-Restoration Condition	
			Value	Rating	Value	Rating
1 - Hydrology		Insert pre- and post restoration data				
2 - Hydraulics	Example	Example	Example	Example	Example	Example
	Floodplain Connectivity	Bank Height Ratio	3.0	Not Functioning	1.0	Functioning
		Entrench-ment Ratio	1.1	Not Functioning	3.0	Functioning
3 – Geomorphology						
4 – Physiochemical						
5 – Biology						

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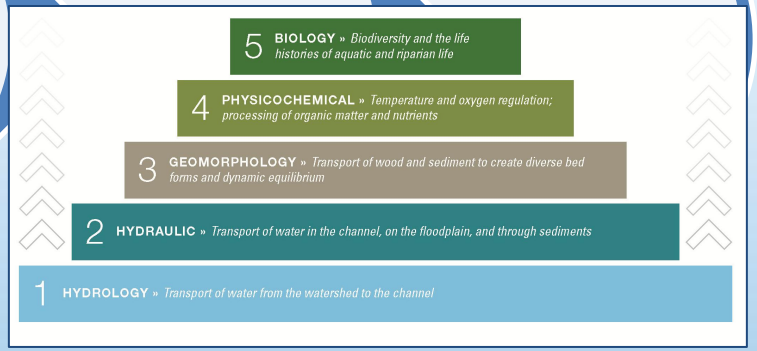
Function-Based Assessment

Restoration Potential

Goals and Objectives



- Goals relate to solving a functional problem
- Objectives describe how the problem will be solved

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Bad Goal

The goal of this project is to improve habitat

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Better Habitat Goals

The goal of this project is to improve native brook trout habitat (Levels 1-3).

Even better – The goal of this project is to increase the biomass of native brook trout populations (Levels 1-5).

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Another Bad Goal

Temperature
Dissolved Oxygen

pH
Conductivity

Nitrate-Nitrogen
Phosphorus

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Better Water Quality Goals

The goal addresses a functional problem

- The goal of this project is to reduce NO3-N from adjacent land uses (Level 4).

The objective tells what will be done to improve the function

- The objectives are to:
  - Improve bedform diversity (Level 3)
  - Establish a 100 foot riparian buffer (Level 3)
  - Provide floodplain connectivity (Level 2)
  - Improve groundwater/surface interaction (Level 2)

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Quantitative Objectives

- Floodplain Connectivity
  - Reduce bank height ratios from 2.0 to 1.0.
  - Increase entrenchment ratio from 1.2 to 3.0.
- Bedform Diversity
  - Convert riffle dominated bedform (95% riffle) to riffle-pool sequence (70/30).
- Streambank erosion
  - Reduce erosion rates by 95%.
  - Reduce erosion rates to reference reach condition.
- Riparian Buffer
  - Increase buffer width from 0 feet to 50 feet.

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- The Solution – Based on all of the previous information.
- Not just to improve dimension, pattern, and profile.

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- Were the goals and objectives achieved?
- How much functional lift was achieved?

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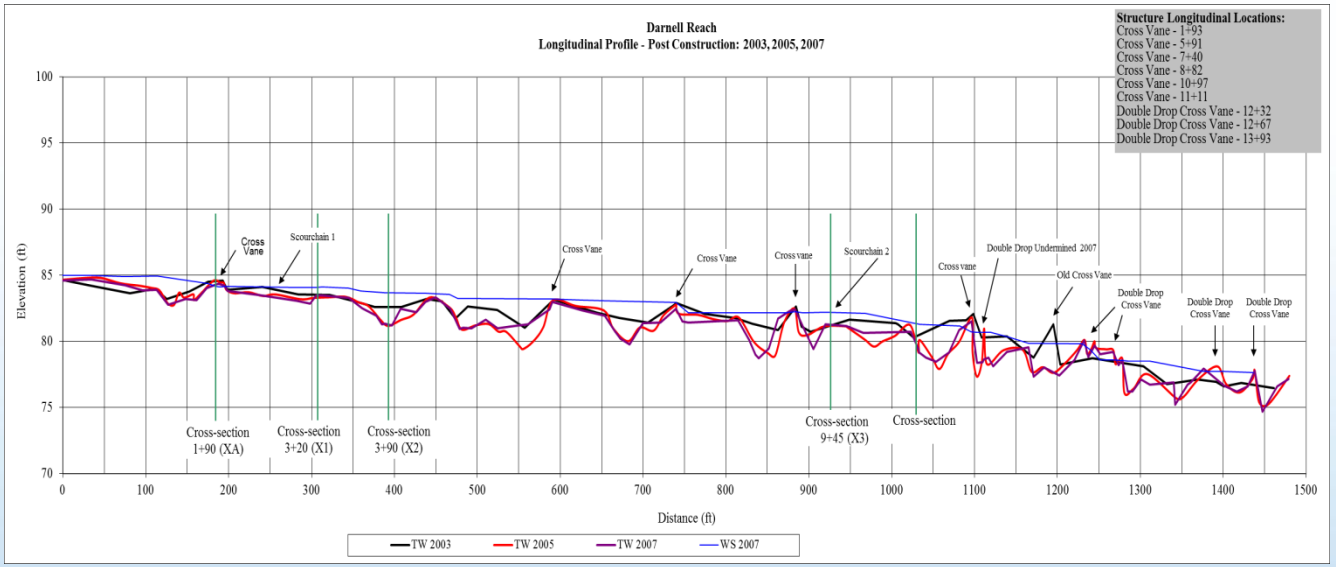
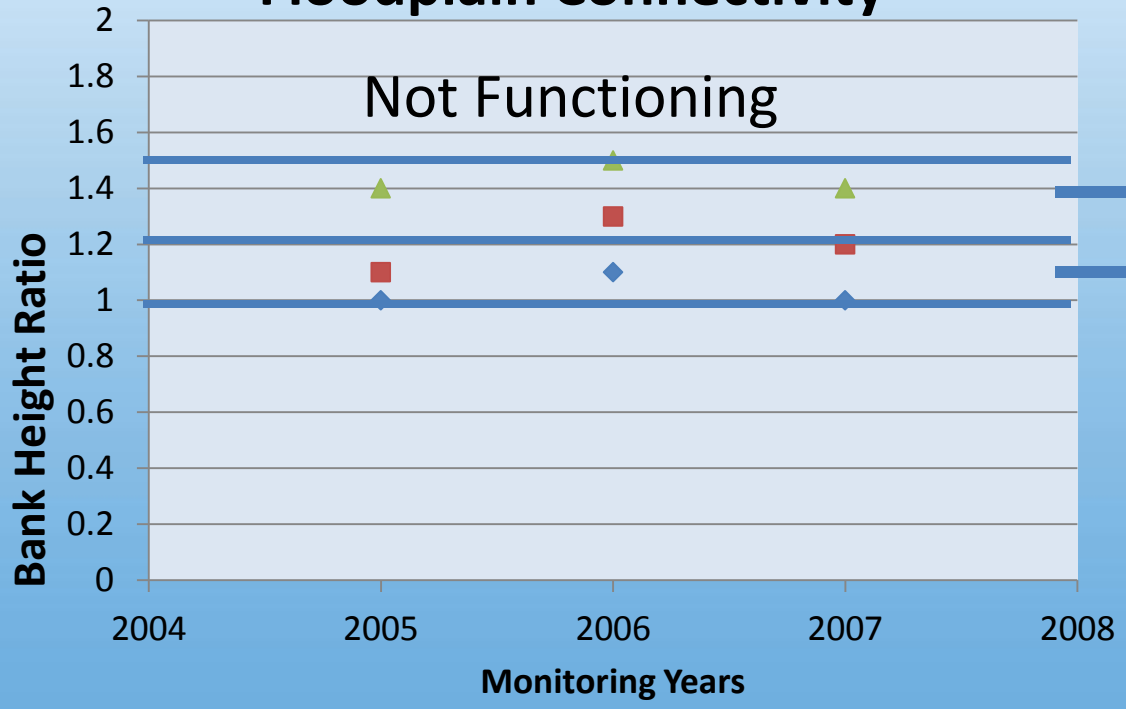


Floodplain Connectivity



Functioning - At-Risk

Functioning

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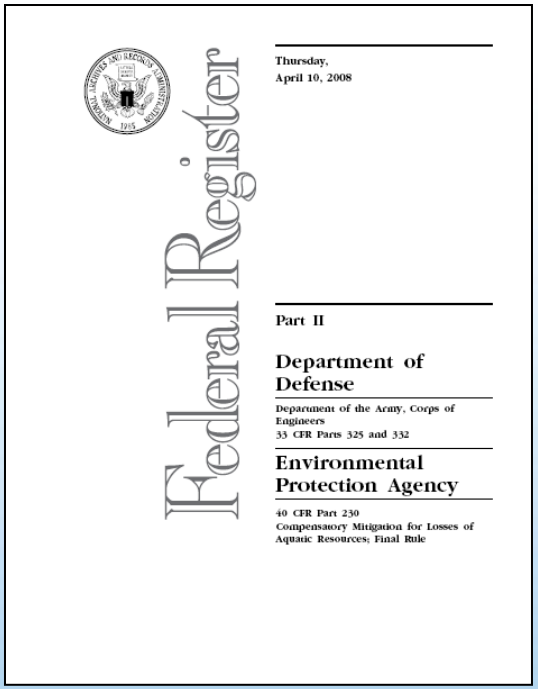
Stream Mitigation


Federal Register

Thursday,
April 10, 2008

Part II

Department of Defense

Department of the Army, Corps of Engineers
33 CFR Parts 325 and 332

Environmental Protection Agency

40 CFR Part 230
Compensatory Mitigation for Losses of Aquatic Resources; Final Rule

- Part of the Clean Water Act (New Rules)
  - Avoid, Minimize, and Mitigate
- Quantify lost functions at proposed impact site and "functional lift" at proposed mitigation site
  - Not net loss
  - Based on a **functional assessment**
- Use of best available science that is practicable
- **Performance standards**

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Debit and Credit Template Structure

- Debits
  - Debit Template 1: Functional **Loss** Determination
  - Debit Template 2: Pre- and Post-**Disturbance** Condition and Rationale
  - Debit Template 3: **Debit** Determination
- Credits
  - Credit Template 1: Functional **Lift** Determination
  - Debit Template 2: Pre- and Post-**Restoration** Condition and Rationale
  - Debit Template 3: **Credit** Determination

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Debit Template 1

Functional Loss Determination

Level and Category	Parameter	Measurement Method	Pre-Disturbance Condition		Predicted Post-Disturbance Condition	
			Value	Rating	Value	Rating
1 - Hydrology						
2 - Hydraulics	Example	Example	Example	Example	Example	Example
	Floodplain Connectivity	**Bank Height Ratio**	**1.0**	**Functioning**	**2.5**	**Not Functioning**
		Entrenchment Ratio	**3.0**	**Functioning**	**1.1**	**Not Functioning**
3 – Geomorphology						
4 – Physiochemical						
5 – Biology						

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Credit Template 1

Functional Lift Determination

Level and Category	Parameter	Measurement Method	Pre-Restoration Condition		Post-Restoration Condition	
			Value	Rating	Value	Rating
1 - Hydrology						
2 - Hydraulics	Example	Example	Example	Example	Example	Example
	Floodplain Connectivity	**Bank Height Ratio**	**3.0**	**Not Functioning**	**1.0**	**Functioning**
		Entrenchment Ratio	**1.1**	**Not Functioning**	**3.0**	**Functioning**
3 – Geomorphology						
4 – Physiochemical						
5 – Biology						

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Debit and Credit Calculations

- Ratios Based on Length
- Debits based on negative changes to Functional Capacity (Functional Loss)
- Credits based on positive changes to Functional Capacity (Functional Lift)

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Key Points

- Restoration activities directly affect Level 2 and 3 Parameters.
  - May occasionally directly affect Level 1.
- Restoration activities along with proper site selection *may* affect Level 4 and 5 Parameters.
- This is a guide to help people think about how functions support each other and how to link restoration approaches with functional lift.
  - It is not a cookbook approach

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Acknowledgement

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- Rich Starr, U.S. Fish and Wildlife Service.